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Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

Mechanical Analysis of HFM Cos (θ) Dipole Model End Cross-section

Deepak Chichili
Engineering and Fabrication Department
Technical Division
Fermilab, Batavia, IL 60510

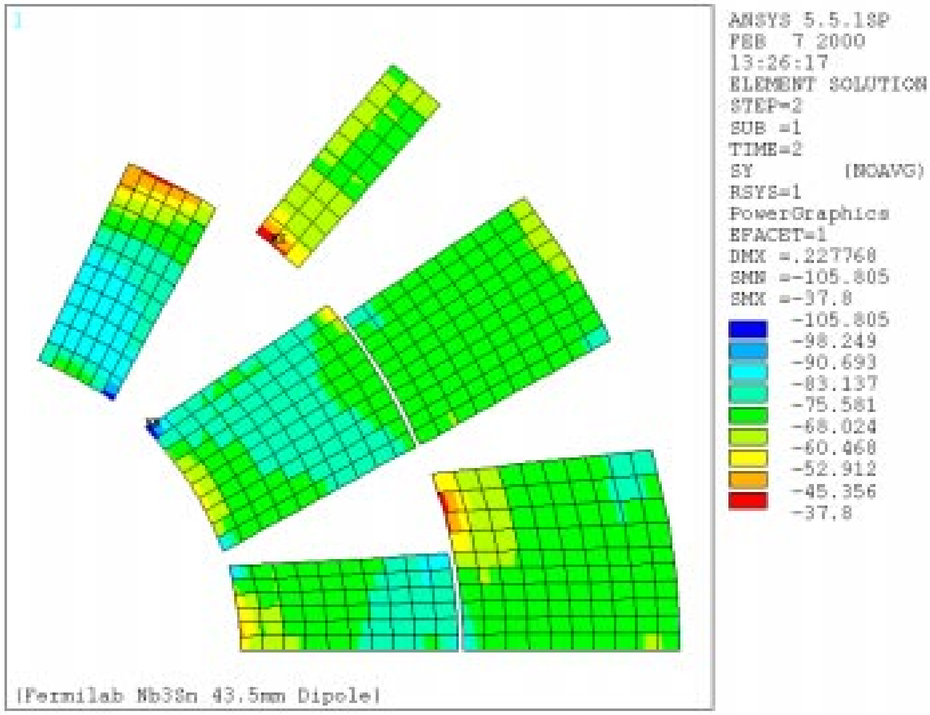
Introduction

The mechanical analysis of the cross section in the straight region has already been completed (TD-99-035). This report presents similar analysis for the cross section of the model in the end region with stainless steel yoke. Note that out of total magnet length of 1000 mm, the center 600 mm is assembled with iron yoke and the remaining 200 mm on either side is assembled with stainless steel yoke. This is to reduce the peak field in the coil ends and to maximize the length of uniform field along the magnet. Since the thermal contraction coefficient of the stainless steel ($1.027 \times 10^{-5}\ K^{-1}$) is different from that of iron ($0.70 \times 10^{-5}\ K^{-1}$) we need to optimize the design parameters in the end region especially the yoke/clamp interference. The goal is to minimize the non uniformity in the coil stress at the interface between the iron and stainless steel yoke pieces.

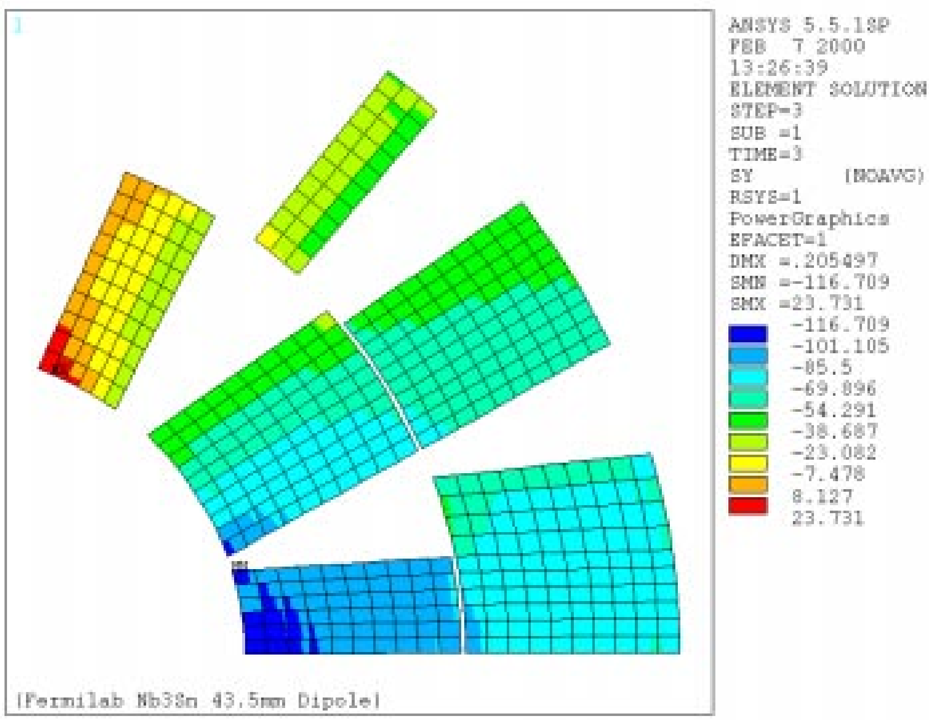
In order to keep the fabrication of the magnet simple, we decided to have the same weld shrinkage along the whole length of the magnet. So the two parameters which could be adjusted are spacer / pole extension interference and yoke/clamp interference. The following section presents the details of the analysis.

Mechanical Analysis

If the iron is replaced with stainless steeel yoke and nothing else is changed (weld shrinkage = 0.4 mm, clamp/yoke interference = 0.3 mm and spacer/pole interference = 0.1 mm) the stress distribution in the coils after cool down and at excitation are as shown in Figs. 1(a) and 1(b) respectively. Note that the stress distribution at room temperature is the same. The peak stress near the pole region of the inner coil at 4.2 K is 105 MPa compared to 122 MPa with iron yoke. On excitation, the pole region comes under tension with stainless steel yoke which is not acceptable.



(a)



(b)

Figure 1: *Azimuthal stress distribution in the coil with stainless steel yoke with the same parameters used with iron yoke; (a) 4.2 K (b) 11 T.*

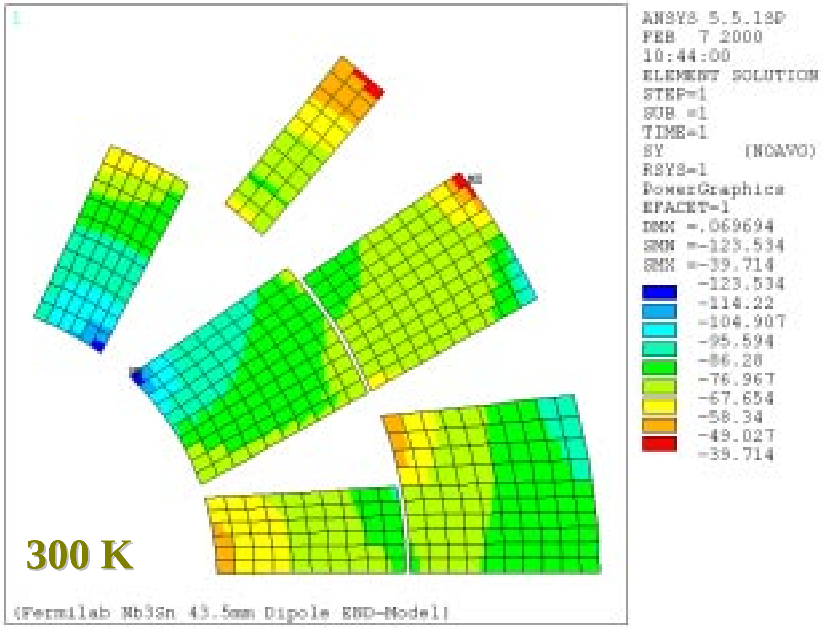
As stated earlier, for fabrication simplicity we wanted to keep the same weld shrinkage for the entire length of the magnet. So in order to increase the stress on cool down so that the coils are still in compression on excitation, we increased the clamp/yoke interference in the end region from 0.3 mm to 0.35 mm. The spacer/pole interference was kept the same.

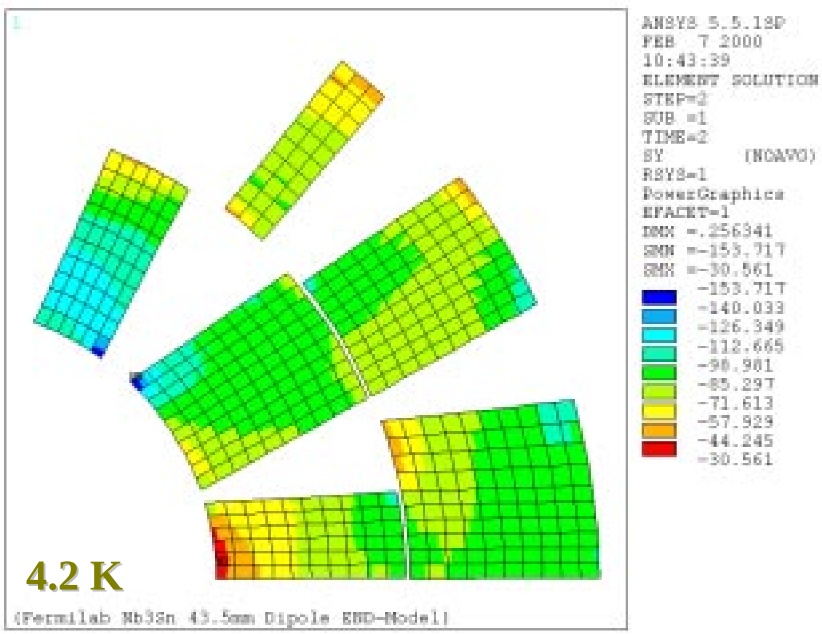
The resultant stress distribution in the coils is shown in the Fig. 2. For comparison, the stress distribution in the coils with iron yoke is also shown. Note that at room temperature the stress near the inner coil pole region with stainless steel yoke is higher than that with iron yoke. This higher stress at room temperature is needed as the drop in the stress due to cool down is more with stainless steel than with iron yoke. If we ignore the local maximum stress near the wedge/coil interface, the peak stress after cool down with stainless steel yoke is about 126 MPa which is close to that of with iron yoke (122 MPa). However the stress at the inner coil mid-plane is slightly higher with stainless steel yoke (30 MPa) than with iron yoke (11 MPa). On excitation the stress distribution looks quite similar.

The displacement contour plots are shown in Fig. 3. Except at room temperature, the displacement profiles are similar both with stainless steel yoke and with iron yoke. The dissimilarities at room temperature is to be expected since we are changing the parameters at room temperature to match the stress distribution on cool down and on excitation.

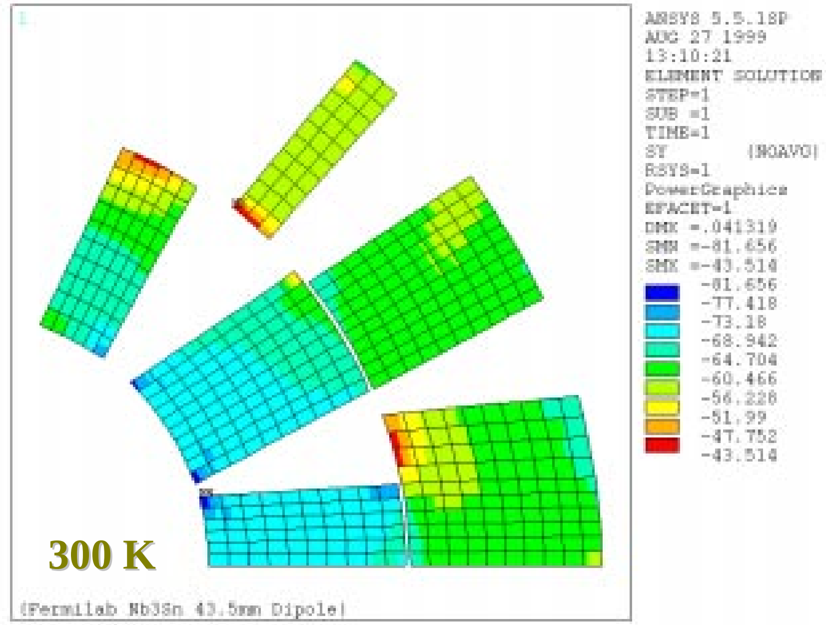
TD-00-046

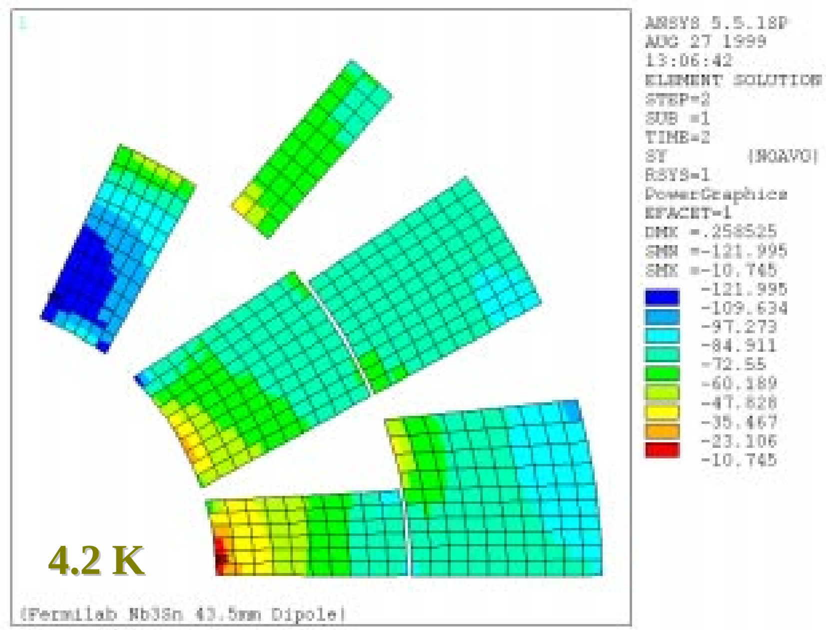
With Stainless Steel Yoke





With Iron Yoke





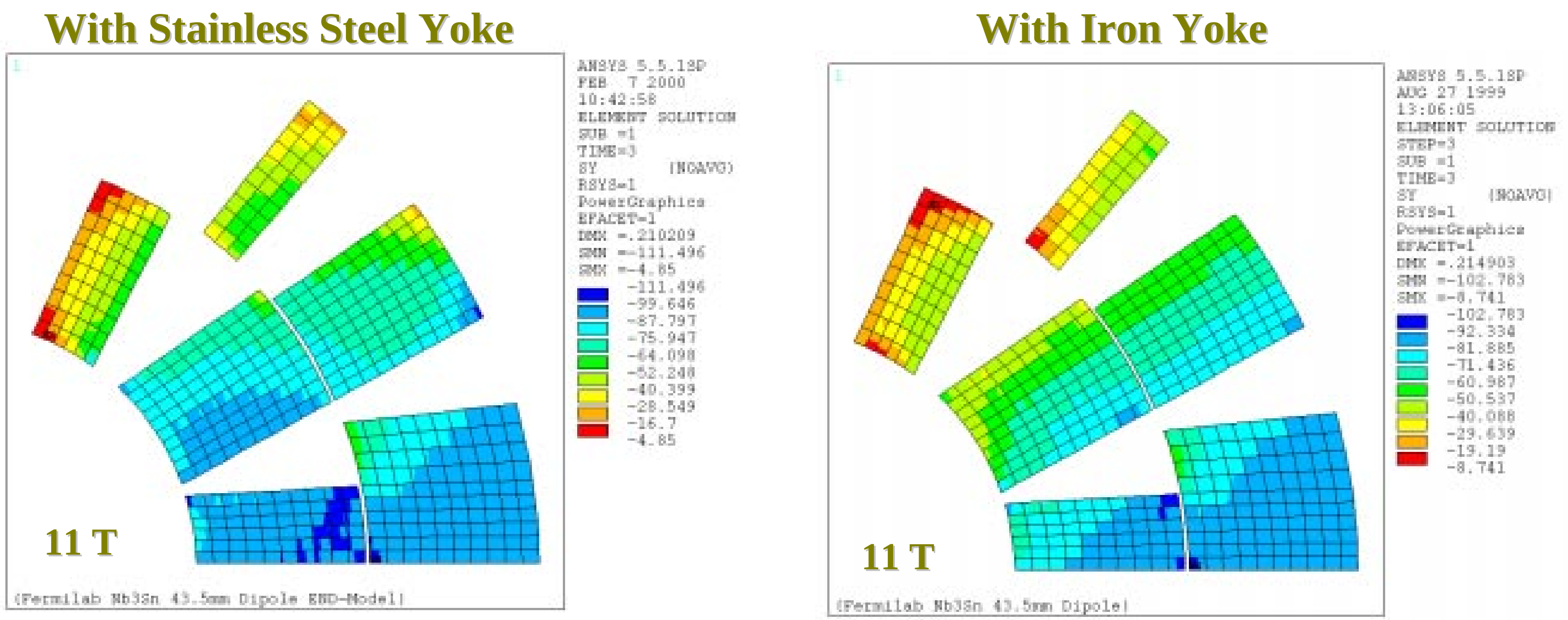
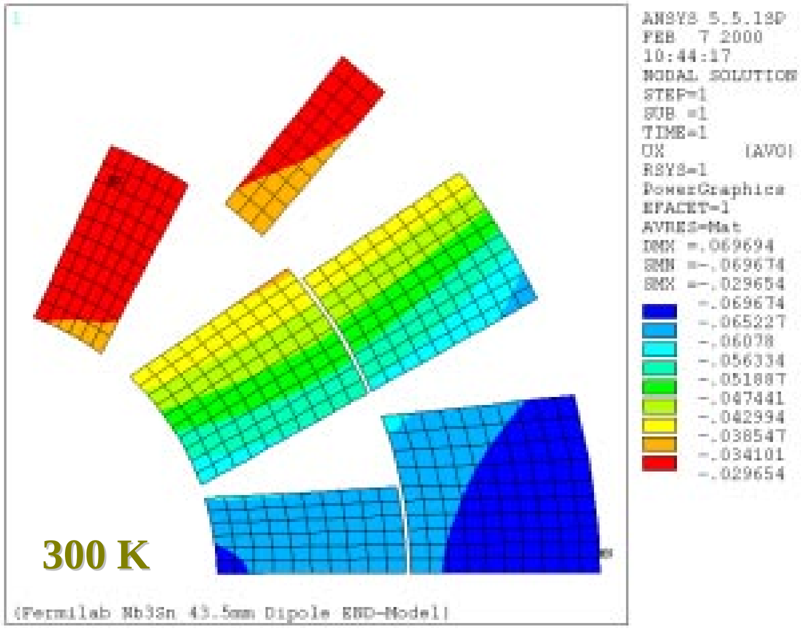
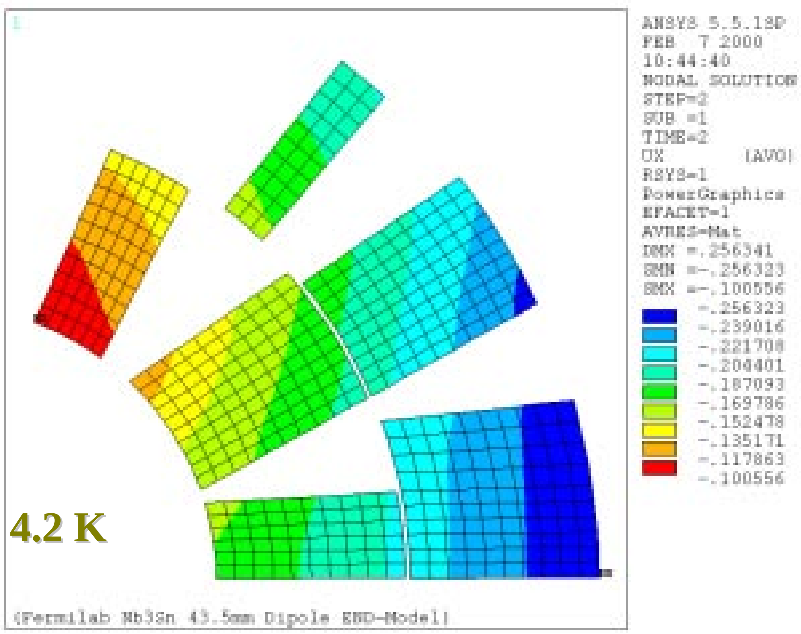


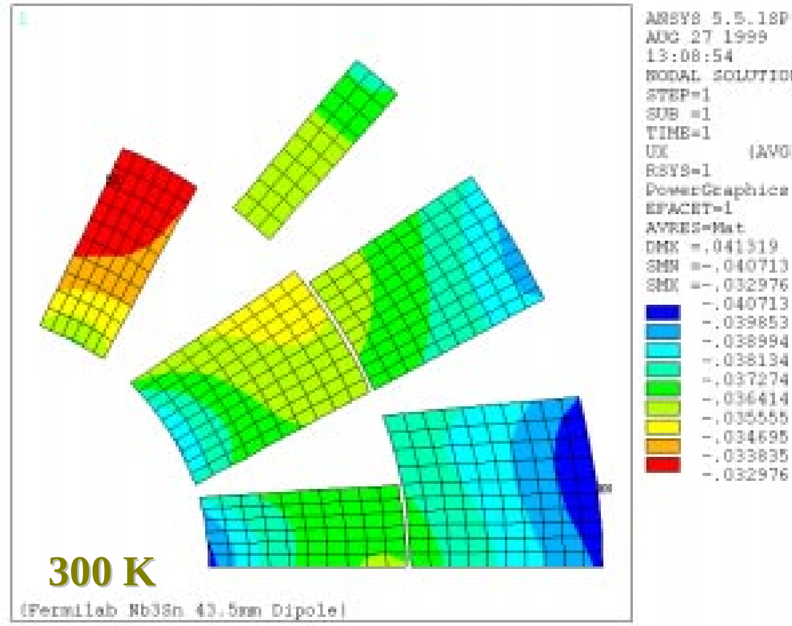
Figure 2: *Azimuthal stress distribution in the coils at room temperature, 4.2 K and at 11 T*

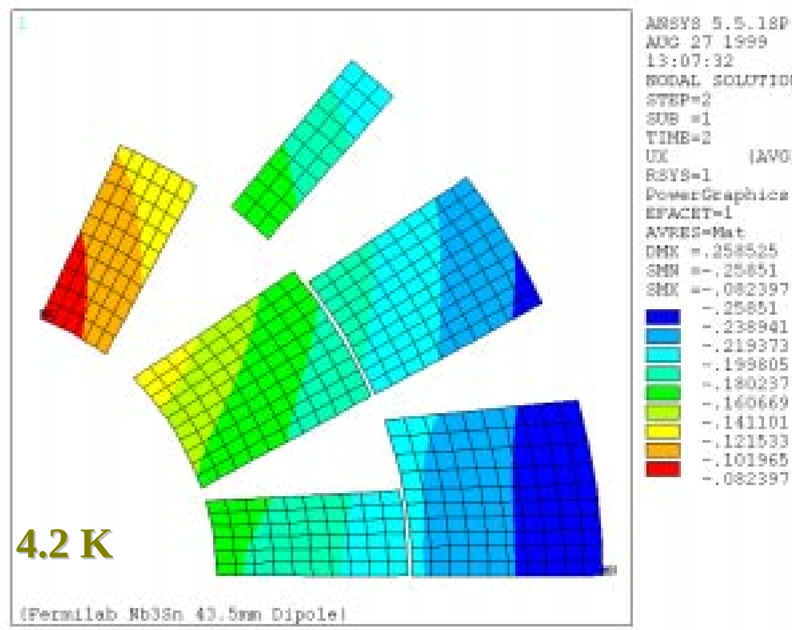
With Stainless Steel Yoke





With Iron Yoke





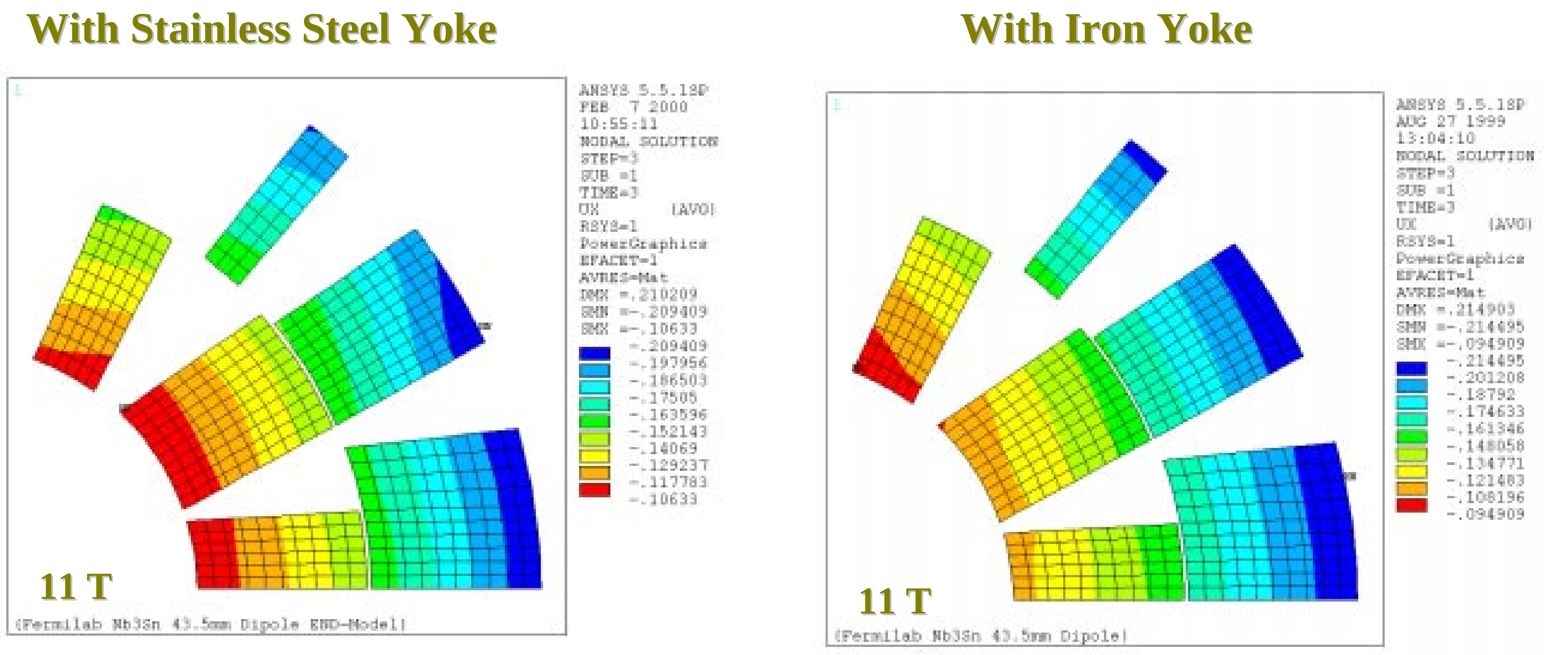


Figure 3: *Radial displacement contour plots at room temperature, 4.2 K and at 11 T.*